Characterizing An Experimental Decelerator For Delivering Nano-Sat Payloads To Planetary Surfaces

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Abstract

NASA Ames Research Center is developing the Small Payload Quick Return (SPQR) system, designed to quickly deliver a small payload from the International Space Station (ISS). The SPQR system uses a unique atmospheric drag device (Exo-Brake) which makes it compatible with crew operations. A crew member would release the system from the ISS to Earth. The atmospheric drag device would deploy, and de-orbit the system in roughly 40 orbits. A tube deployed re-entry vehicle would then allow the payload to enter the atmosphere. At an altitude near 30,000 meters (95,000 feet), a parafoil system would deliver the payload to the surface of Earth. In order to improve the accuracy of the targeting system over the gradual de-orbit process, it was necessary to develop an on-orbit position determination system. A Short Burst Data (SBD) modem offered by satellite phone vendors is to be tested to determine the viability of the uplink/downlink capability. This modem will include a GPS receiver and will transmit its location multiple times per orbit. The position resolution will help accurately characterize the aerodynamics of the atmospheric drag device throughout entry and descent.

The University of Idaho's Near Space Engineering program has worked with NASA Ames to test various subsystems for the SPQR system. The balloon program had been able to serve as a test bed for iterative tests of the telecom system and GPS guided parafoil. The first experimental atmospheric drag device (Exo-Brake) test is scheduled for April 2013. This will consist of a scale model being dropped at 50,000 feet (15000 m). A 3U cube satellite will be delivered to the ISS in June 2013 with Exo-Brake and telemetry systems tested by the Balloon program. Once the atmospheric drag device is properly characterized and tested, the SPQR system could be used to deliver Nano-sat scale payloads to the surface of Mars.

Status

Exo-Brake Characterization

Problem: The first stage re-entry strategy must be characterized by tracking through multiple orbits.

Solution: The joint SJSU/UofI TechEdSat-3P will be deployed from the ISS equipped with an experimental Exo-Brake in November of 2013.

Status: TES-3P was delivered June 7th 2013 to Johnson Space Center.

Exo-Brake Data Collection

Problem: Accurate characterization of the Exo-Brake requires continuous GPS tracking during experiments.

Solution: TES-3P will be equipped with SBD modems capable of down-linking GPS coordinates.

Status: SBD modems flew in April of 2013 proving their viability. TES-3P will further test this system

Accurate Payload Delivery

Problem: Method needed to deliver ISS payload to a particular location on Earth's surface

Solution: Snowflake, the GPS guided parafoil, will deliver the payload to a particular location.

Status: Developed system has been deployed at altitudes up to 50,000 feet via balloons and UAV's.

Overview

Stage 1: Exo-Brake

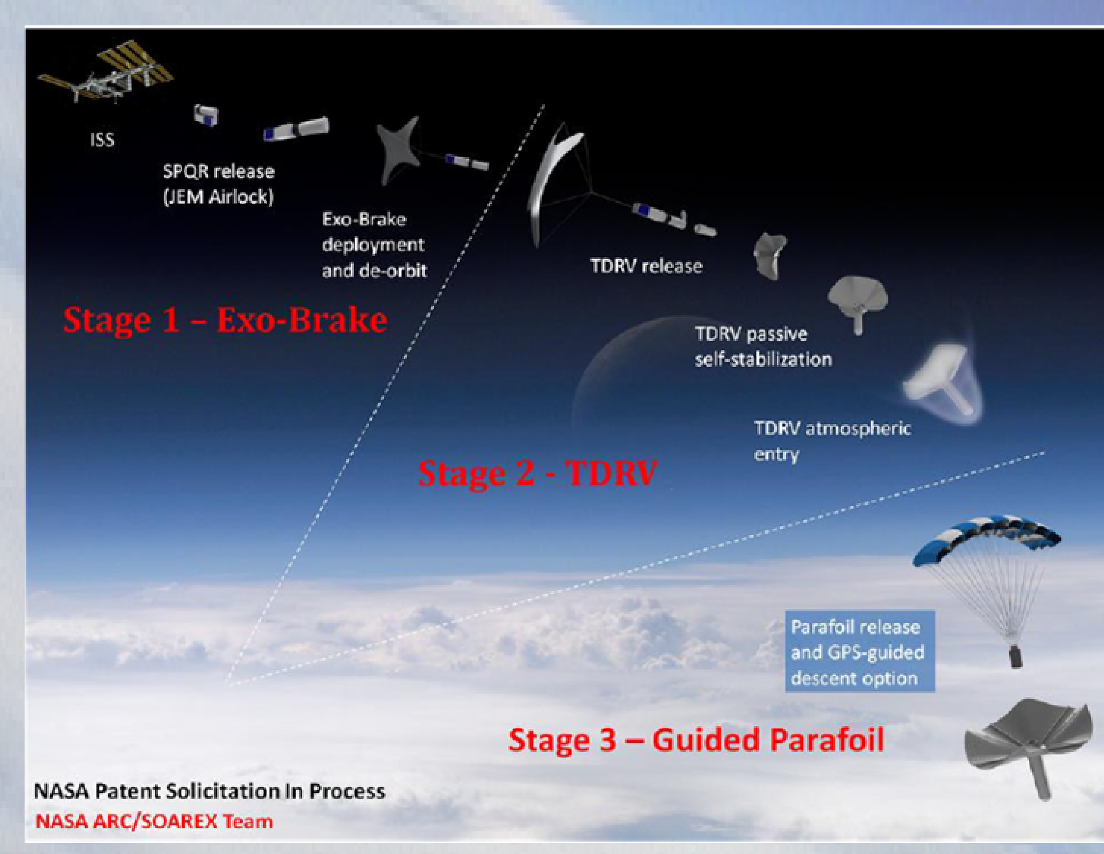
After ISS jettison the Exo-Brake deploys to de-orbit in ~40 orbits.

Stage 2: Tube Deployed Reentry Vehicle

For atmospheric reentry a self stabilizing TDRV is released.

Stage 3: Guided Parafoil

At ~100,000 feet a guided parafoil is deployed which uses GPS to bring the payload to the target destination.



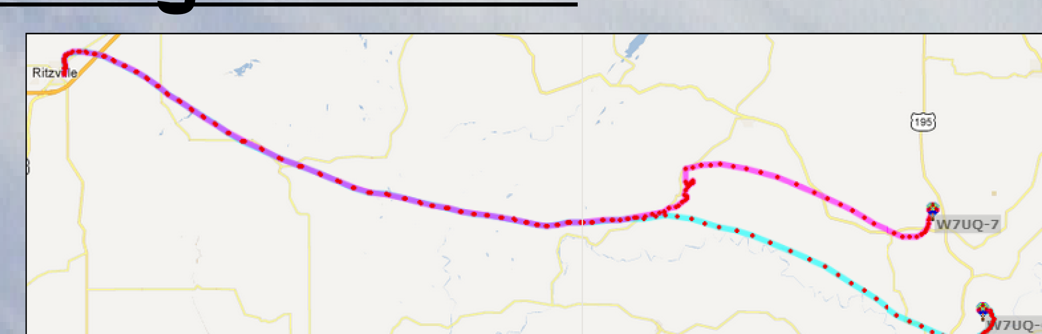
Idaho RISE Flight Results

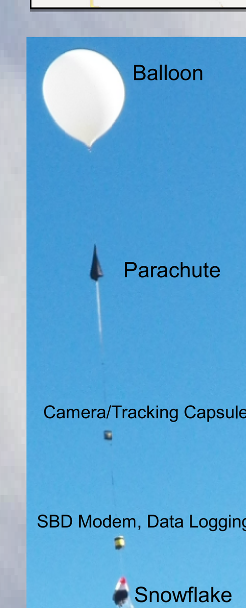
Snowflake (Guided Parafoil)

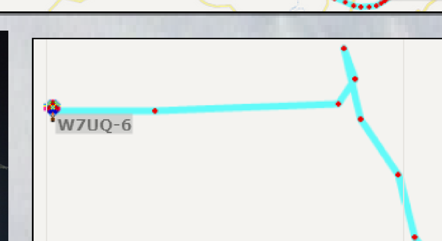
- Cut away from balloon at 50,000 feet
- Parafoil maintained stability at high altitude
- Lack of sufficient thermal insulation caused electronic and servo motor failure
- Steering algorithm and system maneuverability at high altitudes could not be analyzed
- Mounted cameras did not detect audible noise coming from the servo motors, incomplete data log was recorded
- At 2,500 feet, Snowflake warmed up enough to begin steering towards the desired landing target

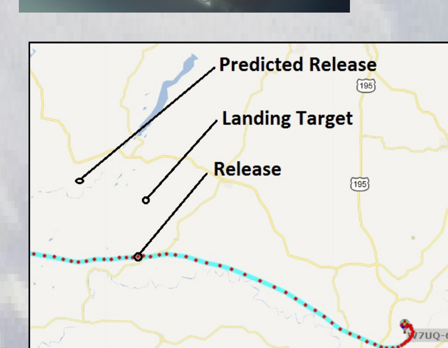
SBD Modem

- 3 successful flights at over 80,000 ft.
- 1 modem failure
- Received 70% of packets transmitted
- 100% commands uplinked during flight (20 / 20)
- Demonstrated ability to command a cut down of Snowflake
- Demonstrated ability to change modem transmission rates and turn off system
- Exposed to -10 deg C, 0.08 atm









From Top: Balloon and Snowflake flight path, Balloon train,Video camera mounted on Snowflake showing Parafoil inflated immediately after cut away*, Snowflake's Final Decent Path*
*Images Courtesy of Joshua Benton

Snowflake Guided Parafoil

Overview

- Adapted by Joshua Benton and Marc Murbach of NASA Ames for use in the SPQR system
- GPS guided parafoil system, capable of delivering a payload to aparticular location.

How it works:

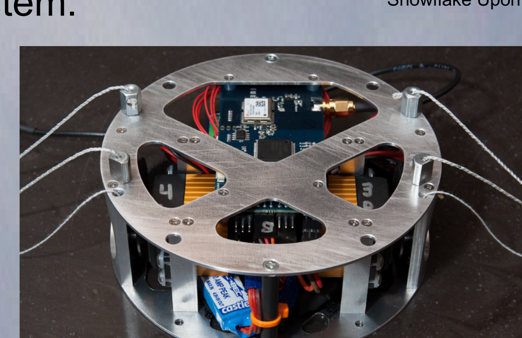
- GPS system determines its location and heading with help from an IMU
- On board algorithm decides which direction Snowflake should head in
- Two servo motors can pull each side of the parafoil to steer the system.

Flight Opportunities

UAV Drops
- Many drops from 5,000 feet and below
- Used to verify steering algorithms before high altitude drops

Idaho High Altitude Balloon Flights
- Flown five times from Fall 2010 to Spring 2012
- Dropped from altitudes of 25,000 feet to 50,000 feet

Snowflake Upon Recovery

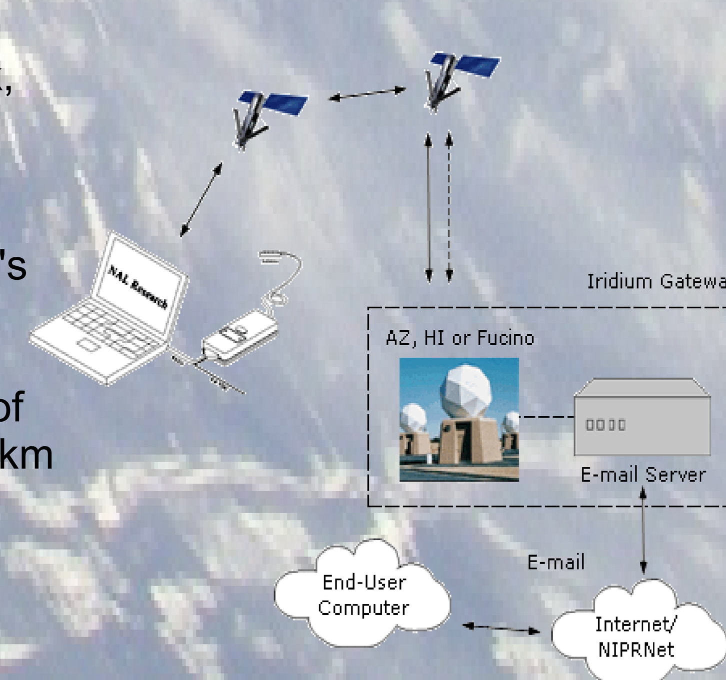


Images courtesy of Joshua Benton

Snowflake Steering and Control System

SBD Modem

- 340 byte downlink, 270 byte uplink
- Satellite Network provides 100% coverage of Earth's surface
- Orbital Flights
  - Expect 2 hours of coverage at 400km
  - 2 MB/day data transfer rate



Goals

Current: Continue Development/ISS Deployment

- Further TES-X iterations jettisoned from the ISS to characterize the Exo-Brake.
- Prove Snowflake accuracy and viability.
- Determine reliability of SBD modems in orbit.

Future: Planetary Deployment

- Obtain space for a SPQR payload on a mission passing near planetary bodies
- Deliver a Nano-Sat payload to the surface of a planet, with special emphasis on Mars

Acknowledgments

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SJSU TES-X Team

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